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Willis, Clarence C.

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THESIS

AN INVESTIGATION OF THE RELATIONSHIPS BETWEEN
AUXILIARY EQUIPMENT READINESS AND AUXILIARY
MAINTENANCE PERSONNEL CHARACTERISTICS

by

Clarence C. Willis

December 1984

Thesis Co-advisors: Ronald A. Weitzman
Thomas G. Swenson

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directly related to equipment downtime on the FFG-7 class ships. The amount of variation in total downtime attributable to personnel characteristics is small, however, when compared with that attributable to ship effects, as measured by average ship downtime. Accounting for ship effects in this study facilitated a meaningful analysis of the personnel-characteristics effects. The results of this analysis indicated that an increase in training coupled with improved selection and retention of relatively higher quality personnel would contribute to a reduction in downtime of auxiliary equipments on FFG-7 class ships.

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An Investigation of the Relationships Between Auxiliary Equipment Readiness and Auxiliary Maintenance Personnel Characteristics

by

Clarence C. Willis
Lieutenant Commander, United States Navy
B.S., United States Naval Academy, 1972

Submitted in partial fulfillment of the requirements for the degree of

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December 1984

ABSTRACT

To evaluate the effectiveness of training similar to that associated with a proposed auxiliary equipment rating, the analysis reported here examined the relationship between auxiliary equipment readiness on eighteen FFG-7 class ships and the quality, experience, and training of the personnel assigned to the ships. More experience, higher numbers of trained personnel, and higher numbers of high school graduates were hypothesized to contribute to lower equipment downtime. Results of the analysis support this hypothesis in the case of quality and training. Increased experience, however, is found to be directly related to equipment downtime on the FFG-7 class ships. The amount of variation in total downtime attributable to personnel characteristics is small, however, when compared with that attributable to ship effects, as measured by average ship downtime. Accounting for ship effects in this study facilitated a meaningful analysis of the personnel-characteristics effects. The results of this analysis indicated that an increase in training coupled with improved selection and retention of relatively higher quality personnel would contribute to a reduction in downtime of auxiliary equipments on FFG-7 class ships.

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I. INTRODUCTION

A. RESOURCES AND READINESS

In recent years, the U. S. Navy has been under increasing pressure to justify expenditures for proposed resources by demonstrating their impact upon military readiness. Demonstration of the link of resources to readiness is difficult. The elusive entity called readiness ultimately refers to the ability of the Navy to perform assigned wartime tasks. The measures which are used to assess readiness are, in fact, proxy measures of the organization's ability to fight and win at war. Since fighting wars merely to assess the ability of units to perform their wartime missions is impractical, the Navy uses readiness reports from operational commanders and exercise or inspection reports to assess its readiness [Ref. 1].

Personnel resources needed to achieve readiness are both expensive and difficult to manage. Placing the right person from the Navy's half million personnel in the right position with the appropriate skills at the proper time makes the manpower manager's task challenging.

The relationships between personnel policy implementation and readiness are complex and often confusing. In some cases, the high quality of the personnel assigned may offset the impact of insufficient numbers of personnel. Depending upon the nature of the tasks personnel are required to perform, the opposite case, substituting quantity for quality, may adversely affect readiness. Better decisions concerning resource allocation can be made if the costs and effects on readiness of changes in personnel quality and quantity are known. Then, comparison with the costs and

effect on readiness of other resource expenditures such as new systems acquisitions or operating funds can be made intelligently. The purpose of this thesis is to analyze the effect of auxiliary equipment maintenance training upon auxiliary equipment readiness as measured by CASREP downtime.

B. AUXILIARY EQUIPMENT

As the Navy's ships and systems become more complex, they grow more dependent upon auxiliary equipments. "Auxiliary equipments are defined as any shipboard machinery, equipments or systems under the cognizance of the ship's engineer officer which are not directly involved in the operations of the ships's main propulsion system(s)" [Ref. 2]. A listing of typical surface shipboard auxiliary equipments is presented in figure 1.1. Many, if not all, of these equipments have a functional relationship to a ship's operational capability. Essential electronics systems such as radars, weapons systems and communication equipments depend upon auxiliary equipments for cooling and dry air essential to their operation. Inoperability of the aircraft or weapons elevators on aircraft carriers can incapacitate the Navy's most costly aircraft. Failure of cargo systems on underway replenishment ships can result in their inability to perform their primary mission. Steering gear, one of the most common auxiliary equipments, is critical for the accomplishment of every ship's mission. The diversity of auxiliary equipments is one source of the problems associated with them. As can be seen from figure 1.1, they are combinations of hydraulic, pneumatic, electrical, electronic, steam, mechanical and cryogenic systems.

The increasing importance of auxiliary equipment to accomplishment of the Navy's missions coincides with a trend

Galley and Scullery Equipment
Laundry Equipment
Topside Winches, Davits and Windlasses
Telescoping Helicopter Hangers
Fin Stabilizers
Air Compressors(low, medium and high pressure)
Electronics Cooling Water Systems
Electronics Dry Air Systems
Steering Gear Systems
Air Conditioning Equipment
Refrigeration Equipment
Cryogenic Equipment
Underway Replenishment Equipment
Elevators and Conveyors
Incinerators and Waste Disposal Equipment
Heat Recovery and Electrical Evaporators

Figure 1.1 Typical Surface Ship Auxiliary Equipments

toward increased complexity in auxiliary equipments as modern technologies are incorporated into auxiliary systems. For example, in the past the control mechanism for auxiliary equipment may have been a simple fly-weight governor or a manually operated on-off switch. Today these same functions are performed by electro-hydraulic governors and solid state controls. The continuing trends toward reduced manning and increased automation lead to the conclusion that auxiliary systems will grow more complex in the future.

C. AUXILIARY SPECIALIST RATING PROPOSAL

In 1975 Commander Naval Sea Systems Command (NAVSEA) proposed that a rating, Marine Auxiliariesman (MX), be formed specifically to perform organizational and intermediate level maintenance on auxiliary equipments. At that time, the proposed rating applied to both surface ships and submarines. Then, as today, the Machinist Mate (MM) and Engineman (EN) ratings performed the majority of auxiliary equipment maintenance with support from the Electrician Mate (EM) and Interior Communications (IC) ratings. The reasons listed as justification for the new rating were:

1. identification of personnel with auxiliary maintenance skills by Navy Enlisted Classification Codes (NEC's) only, allowed so much latitude in their assignment that experienced auxiliary maintenance personnel frequently served in areas other than auxiliary maintenance;
2. little reinforcement of auxiliary maintenance skills was achieved in the rating examinations of the source ratings for auxiliary maintainers, EN and MM; and
3. failure to employ skilled auxiliary maintenance technicians in that capacity resulted in attrition of skills which would not occur if they were in a separate rating, consistently employed in auxiliary maintenance.

The rating proposal called for the new MX rating to be formed from the EN and MM ratings.

For a variety of reasons, the auxiliary rating was not approved in 1976. Specific concerns were: the proposed rating's reduction in the commanding officer's latitude in the assignment of personnel within his ship; uncertainty over how many personnel would be required in the new rating; uncertainty about the effect of the recently formed Gas

Turbine rating on the auxiliary maintenance situation; and uncertainty about the effect of forming the proposed ratings from the source ratings EN and MM [Ref. 3]. As a result, the EN and MM ratings still perform the majority of the maintenance on auxiliary equipments even though they are trained primarily for main propulsion duties.

NAVSEA's proposal of a new rating in 1984 quite similar to that disapproved in 1976 points out that the auxiliary equipment maintenance problems are still of concern in some areas of the Navy. In April of 1984, six auxiliary systems were included in the eight equipments identified as having high failure rates by NAVSEA's Detection and Response Technique (DART) program [Ref. 4]. The proposal of an auxiliary equipment rating as a partial solution to auxiliary equipment maintenance problems presumes that a new rating will improve maintenance performance by providing technicians with better training and that improved technician performance will result in less downtime for auxiliary equipments. Also the proposed rating would allow better management of auxiliary equipment maintenance personnel, particularly in the areas of distribution to fill ship manning requirements and in the area of identification and utilization of personnel with auxiliary equipment training or experience.

A critical unknown is whether or not additional training of auxiliary equipment maintenance personnel has any effect upon auxiliary equipment readiness. How to answer this question is a problem, since the exact training the proposed rating would provide cannot be tested. The next best alternative is to examine similar training to see what relationships exist with auxiliary equipment operability.

The Navy Enlisted Classifications listed in figure 1.2 were examined to select those which were most similar in range of abilities and skills to the proposed auxiliary

maintenance technician rating [Ref. 5]. From these NEC's, those serving on the FFG 7 class were selected for analysis of the auxiliary training.

Rating/NEC	Description
MM-4283	High and Low Pressure Cryogenic Technician
MM-4291	Centrifugal Air Conditioning Mechanic
MM-4294 EN-4294*	Refrigeration and Air Conditioning Mechanic
MM-4295	Underway Replenishment Mechanic
MM-4296	Shipboard Elevator Hydraulic/Mechanical Systems Technician
MM-4221	IMA Outside Machine Shop Journeyman
EN-4381*	FFG-7 Class Auxiliaries Mechanical Subsystem Technician
EN-4382*	FFG-7 Class Auxiliaries System Technician
EN-4398	DD 963 Auxiliaries System Technician
EM-4668	Underway Replenishment Electrical Component Maintenance (Denison)
EM-4669	Underway Replenishment Electrical Component Maintenance (United)
EM-4671	Shipboard Elevator Electronic Electrical Systems Technician

*included in analysis

Figure 1.2 Surface Navy Enlisted Classifications (NEC) related to Auxiliary Equipment

II. DISCUSSION AND LITERATURE REVIEW

A. LITERATURE REVIEW

Prior attempts to demonstrate the relationship between readiness and personnel characteristics have produced mixed and often counter-intuitive results. In fact, the results of the prior work lead to the conclusions that even the Navy's "sacred cows"--retention and experience--are not universally good and appropriate to all situations. For example, the personnel who are retained may be merely adequate performers who self select because they are unemployable in the civilian labor market. In that case the Navy may be quietly undermining its senior enlisted leadership five to ten years in the future, while maintaining a laudatory retention rate.

If you ask any Fleet Naval Officer how much off ship training is needed for his sailors or how many sailors he needs, chances are the answer will usually be "MORE!" The manpower research in this area doesn't always support the default answer. In one of the earliest studies in this area, Horowitz and Sherman document a training effect on casualty report (CASREP) downtime only in ratings which maintain complex systems such as Fire Control Technician (FT). In the ratings most similar to the proposed auxiliary maintenance technicians, Machinist Mates (MM) and Boiler Technician (BT), Horowitz and Sherman found that decreases in equipment downtime were associated with increasing total numbers of men, but not their training [Ref. 6]. In a later study of several ratings and classes, McGarvey , Elster and May found:

> "...a higher EN paygrade structure is associated with improved readiness aboard the Spruance Class destroyers (fewer total CASREPS, fewer level-3 CASREPS, improved SPCC Readiness Index and fewer supply downtime hours...." [Ref. 7].

In their conclusions, the same authors state "a cursory review of (our study) does not provide any consistent support for the idea that an older, more experienced, better educated, smarter, more senior, less turbulent, more fully-staffed Navy is a uniformly good idea...." "...simple main effects that may accrue to such ideas are deeply buried in a morass of rating--by--ship class--by attribute interactions" [Ref. 8].

B. FFG 7 AUXILIARY MANNING

The training of the auxiliary maintainers on the FFG 7 class is similar to that proposed for the auxiliary equipment rating. This similarity makes the FFG 7 class well suited for an analysis of the effect of auxiliary equipment training upon auxiliary equipment readiness. The FFG 7 class ships in Figure 2.1 are included in the analysis reported here. The analysis covers the auxiliary maintenance personnel and auxiliary equipment readiness of those ships for 19 quarters, October 1979 through June 1984.

Relatively new, the FFG 7 class has not been extensively analyzed. The lead ship in the class was commissioned in late 1977 and follow on ships were lagged two years behind the lead ship to allow implementation of lessons learned. The ships listed in fig 2.1 had enough operational experience to have a CASREP history. The class has 35 ships in commission already with 16 additional ships scheduled for completion by 1987 [Ref. 9].

SHIP HULL NO.	NAME	COMMISSIONING DATE
FFG07	OLIVER HAZARD PERRY	DEC77
FFG08	MCINERNEY	NOV79
FFG09	WADSWORTH	FEB80
FFG10	DUNCAN	MAY80
FFG11	CLARK	MAY80
FFG12	GEORGE PHILIP	OCT80
FFG13	SAMUEL ELIOT MORRISON	OCT80
FFG14	JOHN H. SIDES	MAY81
FFG15	ESTOCIN	JAN81
FFG16	CLIFTON SPRAUGE	MAR81
FFG19	JOHN A. MOORE	NOV81
FFG20	ANTRIM	SEP81
FFG21	FLATLEY	JUN81
FFG22	FAHRION	JAN82
FFG23	LEWIS B. PULLER	APR82
FFG24	JACK WILLIAMS	SEP81
FFG25	COPELAND	AUG82
FFG26	GALLERY	DEC81

(Source: Janes Fighting Ships 1984-85)

Figure 2.1 Ships covered in Analysis

The manpower requirements for the FFG-7 class from the Ship Manpower Document (SMD) for the Engineman rating are shown in Figure 2.2.

RATE	PRIMARY NEC
ENC	none
EN1	4382
EN1	4294*
EN2	4381
EN2	4381
EN3	4381
EN3	4381
EN3	4294
EN3	none*
ENFN	none*
ENFN	none*
FN	9760*
FN	9760

* indicates billet is designated as Selected Reserve billet on FFG's in the Naval Reserve Force.

Source: OPNAVINST 5320.427A SHIP MANNING DOCUMENT FOR FFG 7

Figure 2.2 SMD Manpower Requirements for the Engineman Rating on the FFG-7 class

The Ship Manning Document (SMD) for the FFG 7 class establishes the requirement for 11 enginemen and 2 nondesignated firemen in the auxiliary division. The SMD also establishes the requirement that 5 of the 11 enginemen hold either the 4382 or 4381 NEC; 2 of the 11 enginemen should hold NEC 4294 (air conditioning and refrigeration) [Ref. 10].

The manning concept of the class--reduced manning--places a premium on the ability of each sailor [Ref. 11]. If training is related to the operability of the ship equipments, perhaps this manning concept will accentuate it. The

FFG7 auxiliary maintenance course is similar in length and content to the proposed pipeline included in NAVSEA's 1976 rating proposal. Additionally, sailors completing the course are awarded Navy Enlisted Classification (NEC) codes which identify them in manpower data records.

C. FFG 7 AUXILIARY TRAINING

The auxiliary maintenance courses being tested for association with auxiliary equipment downtime are taught at Service School Command, Great Lakes, Illinois. The courses are FFG 7 Auxiliary Mechanical Sub-systems Technician Class (Course Identification Number A-652-0233) which results in attainment of NEC 4381; and FFG7 Auxiliary Mechanical Systems Technician (Course Identification Number A-652-0235) which results in attainment of NEC 4382 [Ref. 12] [Ref. 5]. The courses are both training pipelines for the Engineman rating consisting of modules which are described in detail in figure 2.3. The modules provide training in valve maintenance, diesel engine maintenance, hydraulic systems, and air compressor systems, as well as some training in electricity and electronics. The training is specifically tailored to the FFG-7 class ships with operating equipments available for training on many of the systems onboard those ships.

Initially the FFG-7 auxiliary maintenance course was strictly a classroom course with almost no hands-on training. Since November of 1979, when the first equipments for hands-on training were installed, the course has included more and more hands on training [Ref. 14]. Thus, it must be kept in mind that the training examined here has changed over the period in the analysis.

Basic EngineMan CIN A-652-0019
This course provides trainees with training in the systems and associated components required for Engineman "C" school including principles of diesel engines and related equipments.

FFG7 Introduction to Engineering Systems Maintenance Management A-652-0152
This course provides training to engineering personnel assigned to FFG7 class ships with the skills to understand and monitor the operation of the engineering systems. Training on systems parameters of the main engines, high and low pressure air compressors, fuel oil , ballasting electrical distribution, firepumps and firemain system.

FFG7 Auxiliary Mechanical Subsystems Maintenance CIN A-652-0158
This course provides training in the operation and maintenance of high and low pressure air compressor systems, electronic cooling water systems and the incinerator including intermediate level maintenance.

Basis Hydraulics for FFG7 Auxiliaries CIN A-652-0164
This course provides knowledge and skills for Engineman paygrades E-1 to E-5 to maintain hydraulic systems and components. The course covers hydraulic principles, hydraulic piping, tubing, hoses, fluids and seals, hydraulic reservoirs, strainers, filters, hydraulic pumps, valves, basic system component's symbols on schematics.

Detroit Diesel Allision 16 V149T1Ship Service Diesel Generator A-652-0166
This course provides training in the operation and maintenance and repair of the Detroit Diesel 149T1 series engines including disassembly, assembly, functional adjustments, and troubleshooting an operational engine under load.

FFG-7 Class Waste Heat System Maintenance CIN A-652-0167
This course provides training in the operation, maintenance and repair of FFG-7 class waste heat system, including details of construction, functional adjustments and control of abnormal operating conditions.

FFG-7 Class Mechanical Systems Technician CIN A-652-0159 (NEC 4382 only)
This course teaches organizational level maintenance on the mechanical components of the oily water separator, pallet elevator, and auxiliary propulsion system on the FFG-7 class ships.

Source: Service School Command Great Lakes NCA Self Study Report

Figure 2.3 Training courses for Engineman NEC's 4381 and 4382

III. METHODOLOGY

A. DATA

Two data bases were used in this analysis. Defense Manpower Data Center (DMDC), Monterey, California, provided information concerning the Enginemen serving onboard the selected FFG 7 class ships during the period of interest. A second data base containing information on auxiliary equipment casualty reports (CASREPS) was provided by American Management Incorporated of Washington, D.C.

1. Personnel Data

The personnel data were obtained from the DMDC Enlisted Cohort File. The Cohort File contains personnel information on each enlisted man in the Navy and is updated each quarter. Using the time period of the analysis and the Unit Identification Codes (UIC) of the ships in Figure 2.1, the Enginemen who had served on any of the ships during any quarter of interest were selected. Using the programs in Appendix B, these records were processed to generate an observation on each individual for each quarter he was aboard one of the ships in the study. Since the DMDC records contain no reporting-aboard date, this analysis assumes that an individual who was listed onboard a unit at the end of a quarter was onboard for the entire quarter. Enginemen of all paygrades were selected, from designated firemen through master chief petty officer. Non-designated firemen were not included in this analysis since no information exists within the DMDC files that can be used to associate them with the auxiliary division. Thus, the only non-designated firemen included in the study are those who

were subsequently promoted to engineman fireman (ENFN) or above on one of the included ships during the period of the analysis. Each of the records contained the following information: (1) Armed Forces Qualifying Test (AFQT) score, (2) high school degree status, (3) current age in years, (4) years of active duty service, (5) the time onboard the ship in quarters, and (6) the individual's assigned Navy Enlisted Classification Code (NEC), if any.

Next, aggregation of the data for each ship and each quarter was accomplished. The program provided the following information for each ship in each quarter: 1) number of enginemen who were high school graduates, 2) number of enginemen onboard each ship in a quarter who held NEC 4381 or 4382 indicating auxiliary training, 3) number of enginemen onboard each ship in a quarter who held NEC 4294 indicating air conditioning training, 4) number of enginemen onboard each ship in a quarter who held no NEC, 5) the sum of the time onboard for all of the enginemen onboard a ship in a quarter, and 6) the mean AFQT score of the enginemen onboard a ship in a quarter.

2. CASREP Data

The CASREP data base was formed by selecting those Equipment Identification Codes (EIC) associated with the Enginemen rating onboard the FFG 7 class. This data base contained the date the casualty was reported, the date the casualty was corrected, the number of hours the ship reported the repair was delayed while awaiting parts, the name and EIC of the equipment, the maintenance level at which the repair was accomplished and the severity level of the CASREP. These data were processed using the programs in Appendix C to produce a file containing information on the casualties reported by each ship during each quarter. The program computes the number of days of CASREP downtime, the

number of days downtime awaiting parts and the number of days downtime not awaiting parts for each casualty in each of the 19 quarters under analysis. The number of days for each category of downtime (total, awaiting parts, and not awaiting parts) is apportioned to the quarters in which they occurred.

3. Sample

The personnel and CASREP data bases were merged, matching the data by ship and quarter. The resulting data base contained 213 observations. Each observation contained both personnel and CASREP information on a ship during one of the nineteen quarters in the analysis. As shown in figure 2.1 not all ships under analysis here were in commission for the full period of the analysis. Appendix F contains a detailed description of the raw data and the final data base used in this analysis which was formed using the programs in Appendices B through D. Both the raw data and the data used in this analysis are stored on magnetic tape at the Naval Postgraduate School.

B. ANALYSIS

1. Dependent Variables

For this study, total downtime measured in days and its subcomponents downtime awaiting parts and downtime not awaiting parts were used as the dependent variables in regression analysis. These variables and their definitions are listed in figure 3.1.

Variable	Definition
DWNTOT	--the total auxiliary equipment downtime reported by a ship in a quarter measured in days.
DWNSUP	--the total time in days the ship was awaiting parts as reported by the Casualty Report. In cases where parts were ordered but no awaiting parts figure was reported by the ship, DWNSUP was estimated based on requisition submission and receipt dates.
DWNOTHER	--the difference between total downtime and downtime awaiting parts.

Figure 3.1 Dependent Variables

Previous studies have concentrated on the portion of total downtime not awaiting parts as the primary criterion against which maintenance effectiveness should be measured [Ref. 15].

The conceptual framework used in this study is similar to that of a fleet operational commander. The analysis assumes that total downtime is the best criterion to use in adjudging the performance of maintenance personnel. Total downtime is the figure most readily available to operational commanders in assessing ship's equipment readiness. Also, the portion of downtime spent awaiting parts can be reduced by submission of correct requisitions, and aggressive follow-up of supply requisitions. Thus the supply system is really another tool which the technician must be able to use to effect repair to the casualty. Repairs accomplished above the shipboard level (i.e., Depot level, Tender, and Intermediate Maintenance Activity) are also

	DAYS DOWNTIME	PERCENT OF TOTAL
DOWNSUP	17727	63.95
DWNOTHER	9997	36.05
	------	------
DWNTOT	27724	100.00

	DAYS DOWNTIME	PERCENT OF TOTAL
Air Compressors and Air Systems	12771	46.06
Refrigeration and Air Conditioning systems	3892	14.03
Water Systems and Distilling Units	3401	12.26
Steering and Secondary Propulsion Systems	1821	6.56
Main Propulsion Support Systems	1726	6.22
Deck Machinery and Cargo Handling	1703	6.14
Boats and Davits	1494	5.38
Scullery/Galley Equipments	917	3.30
	--------	--------
TOTAL	27724	100.00

Figure 3.2 Categories of Downtime

considered responsive to the quantity and quality of the maintenance personnel assigned to the ship. The ship that submits correct work requests and frequently checks the status of its jobs under repair by outside activities inevitably receives faster, better repair work than ships which

don't. Figure 3.2 displays the amount of downtime subdivided into categories, awaiting parts and not awaiting parts, as well as, the percentage of downtime for each major equipment category.

No attempt was made to account for the different severity levels of CASREPS in this analysis since most of the CASREPS were of the same level, C-2 (marginal degradation of mission). It is difficult to describe, in an academically acceptable way, the intense pressure on ships

Variable	Definition
WEITZ	--a control variable equal to the mean auxiliary equipment downtime per each ship (measured in days).
NRAUXTEX	--the number of Enginemen onboard a ship in a specific quarter with auxiliary equipment training (NEC 4381 or 4382).
NRACTEX	--the number of Enginemen onboard a ship during a specific quarter with air conditioning training NEC 4294.
NRNONNEC	--the number of Enginemen onboard a ship in a specific quarter who had no NEC assigned.
NRHSGRAD	--the number of Enginemen onboard a ship during a specific quarter who had completed high school.
QTRSEXP	--total quarters of experience onboard; the sum of the quarters onboard of all of the Enginemen assigned to a ship during a specific quarter.

Figure 3.3 Control and Independent Variables

to correct equipment casualties reported by CASREP. If an equipment is reported by CASREP, the maintenance personnel are (or should be) doing everything they can to repair the inoperative equipment. Thus, the severity level of the CASREP lends little clarification of the relationships under investigation.

2. Independent Variables

In order to determine the effect of training and other personnel characteristics upon auxiliary equipment downtime, it was necessary to account for additional factors that affect equipment downtime. Some of these factors,which differ from ship to ship, are equipment design, ship age, personnel morale and motivation, deployment and operating schedules, and the willingness of commanding officers to submit CASREPS. The variable used to account for the effects other than personnel characteristics is each ship's quarterly average auxiliary equipment downtime over the period of the analysis (variable WEITZ). This ship variable thus serves as a control variable.

The independent variables used in the analysis are defined in figure 3.3. In order to allow a more meaningful interpretation of the coefficients of regression for the independent variables, numerical values instead of fill ratios were used. This use allows the coefficient of the independent variable to be interpreted <u>cautiously</u> as the change in total downtime that would result from the addition of one man with the characteristic described by the independent variable. In the case of the experience measure in the model (variable QTRSEXP), the coefficient of regression may be interpreted as the change in downtime resulting from one engineman remaining onboard for 1 additional quarter. It must be kept in mind that interpretation of the coefficient of regression in this manner invokes the assumption that all other variables are held constant!

3. Method and Model

The basic model used for this analysis includes total CASREP downtime (variable DWNTOT) as the criterion against which the effects of the independent variables are measured. Other models using downtime awaiting parts (variable DWNSUP) and downtime not awaiting parts (variable DWNOTHER) as the dependent variables are examined briefly. The independent variables include static measures of the training, quality, and experience of the enginemen in the auxiliary maintenance division on the FFG-7 class ships. The measures of personnel training are the number of trained enginemen (variables NRAUXTEX and NRACTEX) and the number of untrained enginemen (variable NRNONNEC). The measure of personnel quality in the model is the number of enginemen who are high school graduates (variable NRHSGRAD). The measure of experience in the model is the total number of quarters the enginemen on a ship have spent on that ship (variable QTRSEXP). Simple descriptive statistics for all of the variables included in the analysis are shown in figure 3.4.

Intuitively acceptable results from this analysis would be an increase in downtime associated with increases in the control variable (variable WEITZ) and with increases in the number of untrained enginemen (variable NRNONNEC). We would expect a decrease in downtime to be associated with increased numbers of trained individuals onboard (variables NRAUXTEX and NRACTEX) and with increased experience (variable QTRSEXP).

Regression analysis was used to determine the linear-composite weights as well as the significance of the independent variables in their relationship to each dependent variable. Appendix E displays an example of the programs used to conduct the regression analysis. Both the

VARIABLE	N	MEAN	STD ERROR OF MEAN	MINIMUM VALUE	MAXIMUM VALUE	STANDARD DEVIATION	VARIANCE
			Dependent Variables				
DWNTOT	213	130.16	8.23	1.00	696.00	120.11	14427.05
DWNSUP	213	79.56	5.72	0.00	506.90	85.43	7298.38
DWNOTHER	213	46.93	3.72	0.00	279.00	54.28	2946.39
			Independent Variables				
MNAFQT	213	45.09	0.70	0.00*	88.00	11.63	135.30
MNYRADS	213	6.54	0.11	3.29	20.00	1.89	3.59
NRACTEX	213	1.42	0.05	0.00	4.00	0.89	0.79
NRAUXTEX	213	2.05	0.11	0.00	7.00	1.89	3.58
NRHSGRAD	213	7.10	0.15	0.00	13.00	2.44	5.93
NRNONNEC	213	5.03	0.16	0.00	14.00	2.66	7.06
MNPAYGRD	213	4.42	0.03	3.43	7.00	0.54	0.29
QTRSEXP	213	41.25	1.28	1.00	101.00	21.30	453.71
WILQIND	213	36.75	0.61	5.00	65.00	10.14	102.86
WEITZ	213	114.15	4.48	17.45	268.05	74.34	5525.46

* Some senior Enginemen had no record of AFQT Score.

Figure 3.4 Simple Statistics for Variables Used in Analysis

overall R-square value for the entire model and each regression coefficient was tested against the $p<.05$ criterion of statistical significance. The overall null hypothesis is that the independent personnel variables are not significantly related to total CASREP downtime.

To cross-validate the regression results, the total data set containing 213 cases was divided into two parts, one containing 2/3 of the total (n=142), subsequently called the predictor sample. This sample was used to develop an equation for total downtime as a function of the independent variables. The equation developed was then used to predict the total downtime for the smaller portion of the total data set containing 1/3 of the total (n=71), subsequently referred to as the test sample. The cross-validity correlation between the actual downtime for the test sample and the predicted downtime for the test sample was calculated to determine the accuracy of the developed equation.

Upon completion of the cross-validity correlations, regression analysis was conducted on the entire sample to obtain the most reliable coefficients of regression using the same model as in the cross-validity correlation. The full data set was also used to examine the relationships of the ship effect variable (WEITZ) to the other independent variables in the model, and to develop equations using downtime not awaiting parts (DWNOTHER) and downtime awaiting parts as the dependent variables (DWNSUP).

IV. RESULTS

A. CROSS-VALIDATION

The results of the regression conducted on the predictor sample in the cross-validation study are displayed in figure

DEPENDENT VARIABLE: DWNTOT

SOURCE	DF	F VALUE	PROB>F
MODEL	6	13.727	0.0001
ERROR	135		
C TOTAL	141		

R-SQUARE	0.3789
ADJ R-SQ	0.3513

INDEPENDENT VARIABLE	COEFFICIENT ESTIMATE	T FOR H0: COEFFICIENT=0	SIGNIFICANCE
INTERCEP	52.15	1.473	0.2796
WEITZ	0.83	6.787	0.0001
NRHSGRAD	-18.42	-2.624	0.0080
NRAUXTEX	9.62	1.469	0.3101
NRACTEX	-20.07	-1.865	0.0460
NRNONNEC	14.18	1.938	0.0938
QTRSEXP	0.87	1.629	0.1056

Figure 4.1 Results of Regression--Predictor Sample

4.1. The control variable WEITZ, the quality measure NRHSGRAD, and the number of air conditioning technicians NRACTEX are significant and in the expected direction in the equation developed from the predictor sample. The coefficients of regression for all the variables were multiplied by the respective independent variables in the test sample to obtain predicted downtime for the test sample. Then the correlation between the predicted and actual downtime was

calculated. If the equation developed using the predictor sample is reliable for the test sample, the correlation between the predicted downtime and the actual downtime in the test sample should be very close to or equal to the coefficient of correlation in the predictor sample (R=.606).

CORRELATION MATRIX

N = 71

	YHAT	DWNTOT
YHAT	1.00000 0.0000	0.68423 0.0001
DWNTOT	0.68423 0.0001	1.00000 0.0000

Note: Numbers below correlations are two tailed significance levels.

Figure 4.2 Results of Cross-Validity Analysis

The cross-validity analysis is displayed in figure 4.2. The predicted total downtime is variable YHAT and the actual total downtime is variable DWNTOT. As shown in the figure, the test sample correlation is r=.684, very close to (in fact higher than) .606, the expected value. This result confirms that the developed model is reliable in predicting the actual downtime based on the independent variables.

B. FULL SAMPLE REGRESSION ANALYSIS

The results of the regression conducted on the full sample (n=213) are shown in figure 4.3. The resulting R-square value for the equation is .4134, corresponding to a multiple correlation of r=.64. The expected relationships

DEPENDENT VARIABLE: DWNTOT

SOURCE	DF	F VALUE	PROB>F
MODEL	6	24.196	0.0001
ERROR	206		
TOTAL	213		

R-SQUARE	0.4134
ADJ R-SQ	0.3963

VARIABLE	COEFFICIENT ESTIMATE	T FOR H0: COEFFICIENT=0	SIGNIFICANCE
INTERCEP	46.657	1.227	0.2211
WEITZ	0.87	9.549	0.0001
NRHSGRAD	-23.57	-4.313	0.0001
NRAUXTEX	13.58	1.871	0.0627
NRACTEX	-14.04	-1.806	0.0724
NRNONNEC	16.97	2.656	0.0085
*QTRSEXP	1.07	2.552	0.0114

*Counter-intuitive result

Figure 4.3 Results of Full Sample Regression

with total downtime (DWNTOT) are present in the case of NRHSGRAD and NRNONNEC, as well as the control variable (WEITZ). The results indicate that increasing the number of enginemen who are high school graduates (variable NRHSGRAD) onboard the FFG-7 class ships would result in decreased total downtime. Similarly, reducing the number of untrained enginemen onboard (variable NRNONNEC) would also reduce total downtime. However, counter-intuitive results were obtained in the case of the experience measure (variable QTRSEXP). The full model regression indicates that experience is directly, rather than inversely, related to total downtime. Unfortunately, the variables NRAUXTEX and NRACTEX are not significant in the full-sample regression model. Thus, the full regression model does not identify which type of trained engineman (auxiliary trained or air conditioning

DEPENDENT VARIABLE: DWNSUP

SOURCE	DF	F VALUE	PROB>F
MODEL	6	24.422	0.0001
ERROR	206		
C TOTAL	212		

R-SQUARE	0.4157
ADJ R-Square	0.3986

VARIABLE	DF	COEFFICIENT ESTIMATE	T FOR H0: COEFFICIENT=0	SIGNIFICANCE
INTERCEP	1	28.913082	1.069	0.2863
WEITZ	1	0.611652	9.344	0.0001
NRACTEX	1	-15.861772	-2.866	0.0046
NRAUXTEX	1	3.915423	0.758	0.4491
NRNONNEC	1	8.316769	1.829	0.0689
NRHSGRAD	1	-12.589397	-3.237	0.0014
*QTRSEXP	1	0.907701	3.032	0.0027

DEPENDENT VARIABLE: DWNOTHER

SOURCE	DF	F VALUE	PROB>F
MODEL	6	8.024	0.0001
ERROR	206		
C TOTAL	212		

R-SQUARE	0.1894
ADJ R-SQ	0.1658

VARIABLE	COEFFICIENT ESTIMATE	T FOR H0: COEFFICIENT=0	SIGNIFICANCE
INTERCEP	17.907417	0.887	0.3762
WEITZ	0.267005	5.463	0.0001
NRACTEX	1.771841	0.429	0.6685
*NRAUXTEX	9.608415	2.492	0.0135
NRNONNEC	8.607635	2.535	0.0120
NRHSGRAD	-10.952648	-3.772	0.0002
QTRSEXP	0.169503	0.758	0.4491

* Counter-intuitive result

Figure 4.4 Results of Regression with Dependent Variables DWNTOT and DWNSUP

trained) we should add to obtain the the decrease in readiness indicated by reducing the number of untrained individuals onboard.

The full model was also used in regression analysis to examine the relationship of the personnel characteristics to

the components of total downtime (variables DWNSUP and DWNOTHER). The results are displayed in figure 4.4. Surprisingly, personnel characteristics are more strongly associated with downtime awaiting parts (variable DWNSUP) than with downtime not awaiting parts (variable DWNOTHER). This finding may be a result of the ship class maintenance plan, Modular Scheduled Repair, which periodically replaces equipments based on a predetermined failure rate and calls for much of the maintenance on these ships to be accomplished ashore [Ref. 16]. The replacement of complete equipments may eliminate a significant amount of equipment disassembly and troubleshooting. Repair work accomplished by repair activities ashore should generally be accomplished faster than aboard the ship because of their superior maintenance facilities. Both of these cases would reduce DWNOTHER separately and independently of the personnel characteristics of the maintenance personnel onboard.

The control variable WEITZ is, as expected, directly related to both DWNSUP and DWNOTHER. The quality measure, NRHSGRAD, is the only variable inversely related to both DWNSUP and DWNOTHER. Apparently personnel quality is an important determinant for all categories of downtime on the individual ships. NRACTEX is inversely related to DWNSUP but not to DWNOTHER. Training as indicated by the number of trained air conditioning technicians is related significantly in the expected direction to downtime awaiting parts but not to downtime other. The number of untrained technicians is significant and in the expected direction in the model for downtime other but not for downtime awaiting parts. These anomalous training results may reflect multicollinearity among the three training variables (NRAUXTEX, NRACTEX, and NRNONNEC).

In any case, these results raise more questions than they resolve, but certainly they point out the complexity of

the relationships among personnel quantity, quality, training, and experience. At a minimum these results provide support to the belief that personnel characteristics can affect downtime awaiting parts. As in the full regression model, the effects of WEITZ and NRHSGRAD are in the expected direction and significant: the dependent variables increase with an increase in average downtime and decrease with an increase of the number of high school graduates onboard. The significant positive relationship of the number of untrained enginemen (variable NRNONNEC) with total downtime not awaiting parts (variable DWNOTHER) seems to indicate that larger numbers of untrained personnel cannot make up for a lack of training in equipment troubleshooting and repair and, therefore, downtime other increases. The significant positive coefficient of the number of auxiliary technicians (NRAUXTEX) in the model with DWNOTHER as the dependent variable is a counter-intuitive result, possibly due to multicollinearity. This together with the counter-intuitive result obtained in the regression on total downtime (DWNTOT), deserves special examination.

C. ANALYSIS OF COUNTER-INTUITIVE RESULTS

The counter-intuitive results obtained in this study prompted further investigation to determine why they occurred. This investigation involved analysis of the correlations between the independent variables of interest and the control variable WEITZ. Figure 4.5 displays the correlations of interest between the control and the other independent and dependent variables. Among these, two strong, significant correlations are evident. The variable of primary interest, NRAUXTEX, has a significant negative correlation (r=-.31) with average ship downtime (WEITZ), and the number of enginemen with no NEC assigned (NRNONNEC) has

CORRELATION MATRIX

(N=213)

	DWNTOT	DWNSUP	DWNOTHER	WEITZ
NRAUXTEX	-0.16230	-0.18398	-0.04719	-0.30940
	0.0178	0.0059	0.4933	0.0001
NRACTEX	-0.22657	-0.22389	-0.09256	-0.08630
	0.0009	0.0008	0.1784	0.1535
NRNONNEC	0.12918	0.15748	0.02594	0.31920
	0.0598	0.0186	0.7066	0.0001
NRHSGRAD	-0.15829	-0.11790	-0.16935	0.08854
	0.0208	0.0789	0.0133	0.1431
QTRSEXP	0.01268	0.02485	-0.01742	-0.02164
	0.8540	0.7121	0.8004	0.7209
WEITZ	0.56345	0.58211	0.34863	1.00000
	0.0001	0.0001	0.0001	0.0000

Figure 4.5 Correlations between the Variables in the Model

a significant positive correlation (r=.32) with average ship downtime (both significant at the .0001 level). These results indicate that, as the number of auxiliary technicians increases, the average downtime decreases, and, as the number of untrained enginemen onboard increases, the average downtime increases. Further evidence that increases in the numbers of auxiliary technicians (variable NRAUXTEX) decrease total downtime is the simple correlation of NRAUXTEX with DWNTOT, which is -.16, in the expected direction and significant at the .01 level. What appears to be happening in the full regression model is that the intuitively acceptable effects are being loaded on the independent variables with the largest variances, leaving the independent variables with less variance to show

counter-intuitive or insignificant results. The strong correlation of the variable NRAUXTEX with the control variable WEITZ indicates that the number of auxiliary technicians is particularly significant in its effect on differences in total downtime among ships.

The remaining counter-intuitive result--that total downtime (variable DWNTOT) increases as experience onboard (variable QTRSEXP) increases--may be due to selective attrition of quality personnel within a ship over time. The quality-attrition hypothesis is consistent with the large inverse within-ship effect of NRHSGRAD on DWNTOT in the full regression model. What appears to be happening is an attrition over time of high school graduates, that leaves fewer high school graduates among the more experienced personnel aboard a ship. This progressive reduction in quality thus increases total ship downtime.

V. CONCLUSIONS AND RECOMMENDATIONS

The results of this analysis support the findings of prior studies that the relationships between materiel readiness and personnel characteristics are complex and fraught with collinearity and interaction. Here again, ship effect variables appear more strongly associated with CASREP downtime than the personnel variables do. Downtime awaiting parts for auxiliary equipments on the FFG-7 class tends to be more predictable using personnel variables than downtime not awaiting parts. Downtime awaiting parts alone accounts for 64 percent of total downtime in this study. This finding could lead to the conclusion that a greater reduction in total downtime would result from expenditures for additional supply parts than for expenditures in the personnel management area. For an example, see [Ref. 17]. The process of selecting a part to stock for future unknown and possibly unknowable casualties from the nearly infinite variety of parts available rapidly diminishes the readiness returned from expenditures in the supply area. For this reason, even though personnel characteristics only account for approximately 15 percent of the variance in total downtime in this study, achieving improved readiness through improvement of personnel management seems more likely in the long term than expenditures in the supply area. While the purchased repair part sits in a bin, awaiting its chance to contribute to readiness, the trained maintenance technician can contribute to the solution of every maintenance problem.

The analysis conducted here indicates that the alterations in personnel policy most likely to decrease auxiliary equipment downtime onboard the FFG-7 class are increasing the number of high school graduates onboard and decreasing

the number of enginemen without specialized training resulting in an Navy Enlisted Classification (NEC). While increasing the number of auxiliary technicians (NEC 4381 and 4382) is not indicated directly by the full model, the strong negative correlation with average total downtime for each ship offers separate and strong evidence that increasing the number of auxiliary technicians onboard the FFG-7 class ships would reduce downtime as well. Failure of this variable to relate significantly to total downtime in the full regression analysis may be because auxiliary maintenance technician efforts are represented by the control variable, average ship quarterly downtime. Expressed in a different manner, the number of auxiliary technicians is a good indicator of differences in average downtime among ships. Increases in the number of auxiliary technicians should be associated with decreases in downtime. While, among the personnel variables, the number of high school graduates on a ship was the most significantly and consistently related to a reduction of auxiliary equipment downtime within a ship over quarters, it was not related to ship downtime averaged over quarters, as the number of auxiliary technicians was.

Experience, as measured by the time onboard a single ship, was directly, rather than inversely, related to CASREP downtime. One possible reason for this counter-intuitive result is selective attrition of superior enginemen to the gas turbine ratings or from military service. If this is in fact the case, a policy change to increase incentives for enginemen to stay in the rating may be indicated to support new diesel main propulsion ships and the growing auxiliary maintenance role for enginemen on gas turbine ships.

Interviews conducted with detailers in the preparation of this thesis indicated that in assignment of personnel to billets requiring Navy Enlisted Classifications, the billet

is considered filled when a match in rating and paygrade is achieved. Only secondary consideration is given to filling the billet with a man holding the required NEC. Based on the analysis here, a reduction in CASREP downtime would occur if the detailing process were modified to fill the NEC requirement as well as the rating and paygrade requirements. Modification of the existing supporting computer systems to accomplish this search for a job-skill match between NEC requirements and the pool of eligibles for transfer could result in a significant reduction in downtime. It may well be that such a method could produce a substantial increase in the fleet-wide fill ratio of NEC billets, without additional training and the requirement to fund it. Ship readiness would benefit.

This analysis examined a model relating training, quality, and experience to CASREP downtime. The regression analysis conducted indicates that for every additional engineman high school graduate assigned to an FFG 7 class ship, CASREP downtime for auxiliary equipments should decrease approximately 20 days per quarter. The reduction in downtime associated with the assignment of an additional auxiliary technician to an FFG-7 class ship is approximately 15 days per quarter. The best policy, of course, is to send high school graduates for training resulting in the NEC, combining both quality and training, to reduce downtime.

The analysis conducted here provides evidence that total auxiliary equipment downtime could be decreased onboard the FFG-7 class by increased placement of trained enginemen onboard (NEC's 4381, 4382, and 4294). The evidence presented in this study indicates that a reduction in downtime is achieveable either by improved management of existing NEC's or by implementation of a new auxiliary equipment rating.

APPENDIX A

GLOSSARY

ABS - SAS program absolute value function.

ACFLAG -SAS program variable.

ADJ - abbreviation for adjusted in the regression printout figures.

AFQT - Armed Forces Qualification Test score.

ALLEMERG -program data set name.

ARPA -- Advanced Research Projects Agency

Auxiliariesman --name used for 1975 proposed auxiliary maintenance technician.

CASREPS --CASualty REPorts which provide information on equipment which is inoperative and affects the ability of a unit to fulfill its mission.

CAS -- SAS program variable name.

CASNPERS --Data set name.

CASSUM --Data set name.

CASTOT --SAS program variable.

CIN -- Computer Identification Number for training courses.

CORDATE -- Variable in CASREP processing program.

Cryogenic --Liquid gas generation systems.

CURAGE -- current age of enginemen on FFG 7 class.

DATAIN -- data set name in programs.

DATAOUT --data set name in programs.

DMDC --Defense Manpower Data Center

downtime --the number of days between the report date of the CASREP and the date the casualty is reported corrected.

DWNOTHER --variable used in analysis equal to the total downtime in a quarter minus the downtime awaiting parts (DWNTOT - DWNSUP).

DWNSUP -- variable used in analysis equal to the number of days in a quarter that the ship was awaiting parts for inoperative equipment reported by CASREP.

DWNTOT --variable used in analysis equal to the total days downtime for a ship in a quarter.

EIC -- equipment identification code, an alphanumeric identifier of equipment.

EM --a rating or occupation in the U.S.NAVY, electrician's mate.

EN --a rating or occupation in the U.S.NAVY, engineman.

ENC --a chief petty officer (paygrade E-7) in the engineman rating.

ENFN --a fireman (paygrade E-3) who is designated in the engineman rating

Engineman --a rating or occupation in the U.S. NAVY which performs maintenance on diesel engines and has secondary duties of auxiliary equipment maintenance.

FFG --Guided missile frigate.

FN --fireman who is not designated for any specific rating.

FT --abbreviation for Fire control Technician.

GT --abbreviation for Greater Than in SAS programs

HSGFLAG --variable name in SAS programs

HYEC --variable in SAS programs and DMDC date element name.

IC -- abbreviation for Interior Communications technician, a NAVY rating.

IMA --Intermediate Maintenance Activity, an off ship repair facility which repairs equipment casualties beyond the capability of the ship.

INTERCEP -- intercept of the y-axis in the regression equation.

ISD --Instructional Systems Development.

LE -- SAS function "less than or equal to."

NEC -- Navy Enlisted Classification; a code which identifies specific skills.

NECFLAG --A variable in the SAS programs.

NEOCS -- Navy Enlisted Occupational Classification System, which manages the numerous ratings and NEC's which identify Navy skills and requirements.

NMPC--Naval Military Personnel Command.

NODAC --Navy Occupational Data Analysis Center.

NPRDC --Navy Personnel Research and Development Center.

NPS --Naval Postgraduate School

NRACTEX --variable used in analysis equal to the number of air conditioning technicians (NEC 4294) onboard a unit in a quarter.

NRAUXTEX --variable used in analysis equal to the number of auxiliary technicians (NEC 4381 and 4382) onboard a unit in a quarter.

NRHSGRAD --variable used in analysis equal to the number of high school graduates among the engineman rating on a ship in a quarter.

NRNONNEC --variable used in analysis equal to the number of enginemen onboard a unit who have no NEC indicating specialized training.

OTHDAY --variable used in SAS programs.

PERFFG --data set name used in programs.

PERSUM --data set name used in programs.

PROB -- abbreviation for probability in regression figures.

QTR --program variable name.

QTRSEXP --variable used in analysis equal to the total number of quarters the enginemen have spent onboard the unit to which they are assigned.

REPDATE--variable used in SAS programs.

REPLEV --variable used in SAS programs.

SAS--Statistical Analysis System, a software package for statistical analysis.

SMD --Ship Manning Document which establishes the manning requirements for ships.

SPCC--Ships' Parts Control Center

ST --SAS program variable name.

SUBSTR --SAS program function.

SUMREP--Data set name in SAS programs.

SUPDAY--variable name used in SAS programs.

SUPHR --variable name used in SAS programs.

TOB --variable name used in SAS programs.

TUIC --variable name used in SAS programs.

UIC-- Unit Identification Code--an unique number for each ship.

WEITZ--a control variable used in analysis equal to the ship's average downtime.

WILQIND--variable used in SAS programs.

YHAT--variable used in analysis, the predicted value of total downtime for the test sample using the equation developed by the predictor sample.

YRADS --variable used in SAS programs.

APPENDIX B

PERSONNEL DATA PROGRAMS

The program below selects Enginemen on the FFG7 class ships from a cohort data base provided by Defense Manpower Data Center, Lt. Jim Moody and Bill King. The desired information is obtained for the 19 quarters of of interest (79Q4 through 84Q2), arrayed over each variable, then the data is swept iteratively to create another file which contains an observation for each of the engineman on the ships for each quarter. The procedure also generates the reporting aboard quarter for each individual, which is the first record in which the appears in the data base for a particular unit.

```
DATA CLOSER;
      INFILE DATAIN;
      INPUT
      @65       HYEC1       PIB1.
      @66       AFQT1       PIB1.
      @67       PAYGRD1     PIB1.
      @87       CURAGE1     PIB1.
      @88       PMOS1       $CHAR7.
      @112      YRADS1      PIB1.
      @123      UIC1        $CHAR6.
      @132      DMOS1       $CHAR7.
   ...(data from the intervening quarters)...
      @1865       HYEC19      PIB1.
      @1866       AFQT19      PIB1.
      @1867       PAYGRD19    PIB1.
      @1887       CURAGE19    PIB1.
      @1888       PMOS19      $CHAR7.
      @1912       YRADS19     PIB1.
      @1923       UIC19       $CHAR6.
      @1932       DMOS19      $CHAR7.; DATA TWO;
    SET CLOSER;
    ARRAY HYEC      HYEC1  HYEC2  HYEC3  HYEC4  HYEC5
                    HYEC6  HYEC7  HYEC8  HYEC9  HYEC10
                    HYEC11 HYEC12 HYEC13 HYEC14 HYEC15
                    HYEC16 HYEC17 HYEC18 HYEC19;
    ARRAY AFQT      AFQT1  AFQT2  AFQT3  AFQT4  AFQT5
                    AFQT6  AFQT7  AFQT8  AFQT9  AFQT10
                    AFQT11 AFQT12 AFQT13 AFQT14 AFQT15
                    AFQT16 AFQT17 AFQT18 AFQT19;
    ARRAY PAYGRD    PAYGRD1  PAYGRD2  PAYGRD3  PAYGRD4  PAYGRD5
                    PAYGRD6  PAYGRD7  PAYGRD8  PAYGRD9  PAYGRD10
                    PAYGRD11 PAYGRD12 PAYGRD13 PAYGRD14 PAYGRD15
                    PAYGRD16 PAYGRD17 PAYGRD18 PAYGRD19;
```

```
    ARRAY CURAGE  CURAGE1  CURAGE2  CURAGE3  CURAGE4  CURAGE5
                  CURAGE6  CURAGE7  CURAGE8  CURAGE9  CURAGE10
                  CURAGE11 CURAGE12 CURAGE13 CURAGE14 CURAGE15
                  CURAGE16 CURAGE17 CURAGE18 CURAGE19;
    ARRAY PMOS    PMOS1  PMOS2  PMOS3  PMOS4  PMOS5
                  PMOS6  PMOS7  PMOS8  PMOS9  PMOS10
                  PMOS11 PMOS12 PMOS13 PMOS14 PMOS15
                  PMOS16 PMOS17 PMOS18 PMOS19;
    ARRAY YRADS   YRADS1  YRADS2  YRADS3  YRADS4  YRADS5
                  YRADS6  YRADS7  YRADS8  YRADS9  YRADS10
                  YRADS11 YRADS12 YRADS13 YRADS14 YRADS15
                  YRADS16 YRADS17 YRADS18 YRADS19;
    ARRAY UIC     UIC1  UIC2  UIC3  UIC4  UIC5
                  UIC6  UIC7  UIC8  UIC9  UIC10
                  UIC11 UIC12 UIC13 UIC14 UIC15
                  UIC16 UIC17 UIC18 UIC19;
    ARRAY DMOS    DMOS1  DMOS2  DMOS3  DMOS4  DMOS5
                  DMOS6  DMOS7  DMOS8  DMOS9  DMOS10
                  DMOS11 DMOS12 DMOS13 DMOS14 DMOS15
                  DMOS16 DMOS17 DMOS18 DMOS19;
    DO OVER HYEC;
      IF HYEC GT 0 THEN DO;
         START = _I_;
         GOTO LABEL1;
         END;
    END;
 LABEL1: FILE DATAOUT;
    DO OVER HYEC;
      IF HYEC GT 0 THEN DO;
         QTR = _I_;
         PUT            HYEC     1-2
                        AFQT     3-5
                        PAYGRD     6
                        CURAGE   7-8
                        PMOS     $CHAR7.
                        YRADS    16-17
                        UIC      $CHAR6.
                        DMOS     $CHAR7.
                        START    31-32
                        QTR      33-34
                        _N_      35-37;
       END;
    END;
```

The portion of the program below generates a Time on Board figure for each individual in the data set. This variable indicates the number of quarters each individual has been onboard the FFG to which he is currently assigned. If the individual goes from one FFG to another, the variable will reflect the number of quarter spent on both ships. If the individual is on an FFG of interest in the early periods, goes ashore or to another class ship and returns to another FFG, the time on variable is restarted for the second tour on an FFG.

```
DATA ONE;
       INFILE DATAIN;
       INPUT          HYEC     1-2
                      AFQT     3-5
                      PAYGRD     6
                      CURAGE   7-8
                      PMOS     $CHAR7.
                      YRADS    16-17
                      UIC      $CHAR6.
                      DMOS     $CHAR7.
                      START    31-32
                      QTR      33-34
                      CASE     35-37;
        TOB = QTR - START + 1; DATA TWO; SET ONE;
  IF SUBSTR(PMOS,1,1)= 'F'; PROC SORT DATA=TWO OUT=SEAM.FFGFMN;
      BY UIC QTR PAYGRD; OPTIONS LINESIZE= 80;  PROC PRINT DATA
= SEAM.FFGFMN;
```

The program below uses the input personnel data and provides an out put summary of the desired data on each ship for each quarter.

```
DATA ONE; SET PERS.PERFFG;
   IF SUBSTR(PMOS,1,2) = 'EN';
   NEC=SUBSTR(PMOS,4,4);
   TUIC=SUBSTR(UIC,4,3); DATA TWO;
  SET ONE;
  IF NEC='4381' OR NEC='4382' THEN NECFLAG=1; ELSE NECFLAG=0;
  IF NEC='4294' THEN ACFLAG=1; ELSE ACFLAG=0;
  IF HYEC GE 6 THEN HSGFLAG=1; ELSE HSGFLAG=0;
  DROP PMOS DMOS; OPTIONS LINESIZE=80; PROC SUMMARY DATA=TWO;
    CLASS UIC QTR;
```

```
    VAR  HYEC  AFQT  PAYGRD CURAGE  YRADS  TOB  NECFLAG  ACFLAG
HSGFLAG;
    OUTPUT OUT=PERSON.PERSUM
           MEAN=MNHYEC MNAFQT MNPAYGRD MNCURAGE MNYRADS MNTOB
           SUM(NECFLAG)=NRAUXTEX SUM(ACFLAG)=NRACTEX
           SUM(HSGFLAG)=NRHSGRAD                SUM(TOB)=QTRSEXP
SUM(PAYGRD)=WILQIND;  OPTIONS  LINESIZE= 80;   PROC PRINT  DATA
=PERSON.PERSUM; TITLE FINAL PROC SUMMARY WITH EN'S ONLY FROM EN
DATA SET; TITLE2 WITH VAR DESIRED FOR REGRESSION; /* //
```

APPENDIX C

CASREP DATA PROCESSING PROGRAMS

> The program below inputs the start and ending date for each of the nineteen quarters, and calculates the total downtime, downtime awaiting parts and downtime other (i.e. not awaiting parts) for each of the nineteen quarters.

```
DATA QUARTER;
  INFORMAT Q1-Q38 YYMMDD6.;
  INPUT Q1-Q38;
  CARDS;
      791001    791231
      800101    800331
      800401    800630
      800701    800930
      801001    801231
      810101    810331
      810401    810630
      810701    810930
      811001    811231
      820101    820331
      820401    820630
      820701    820930
      821001    821231
      830101    830331
      830401    830630
      830701    830930
      831001    831231
      840101    840331
      840401    840630
  ;;;;
    Sample of CASREP1 data                                   ;
                                                             ;
  INPUT UIC REPDATE CORDATE SEVER SUPHR REPLEV EIC $;
        028 780404  780414    2     240    1     YC04 ;
        028 780404  780501    2     480    1     1B03 ;
                                                     ;       DATA
ALOHA;
   SET JOKE.CASREP1;
   SUPHR= ABS(SUPHR);
   IF CORDATE GE 7213;
   IF REPDATE LE 8947; DATA CASREP;
  IF _N_ EQ 1 THEN SET QUARTER;
  SET ALOHA;
    *                                                                ;
    *   ST: quarter starting dates                                   ;
    *   EN: quarter ending dates                                     ;
    *  CAS: proportion of quarter covered by CASREP                  ;
    *                                                                ;
```

```
  ARRAY ST Q1 Q3 Q5 Q7  Q9 Q11  Q13 Q15 Q17 Q19 Q21 Q23 Q25 Q27
Q29
           Q31 Q33 Q35 Q37;
  ARRAY EN Q2 Q4 Q6 Q8 Q10 Q12  Q14 Q16 Q18 Q20 Q22 Q24 Q26 Q28
Q30
           Q32 Q34 Q36 Q38;
  ARRAY CAS  CAS1-CAS19;
  ARRAY SUPDAY  SUPDAY1-SUPDAY19;
  ARRAY OTHDAY  OTHDAY1-OTHDAY19;
  *                                                            ;
  DO OVER ST;
     *                                                         ;
     *  For multi-quarter report, first quarter coverage       ;
     *                                                         ;
     IF ST LE REPDATE AND REPDATE LE  EN AND CORDATE GT EN THEN
DO;
        CAS  = EN - REPDATE;
        END;
     *                                                         ;
     *  For multi-quarter report, middle qtr coverage          ;
     *                                                         ;
     IF ST GE REPDATE AND CORDATE GE EN THEN DO;
        CAS = EN - ST;
        END;
     *                                                         ;
     *  For multi-quarter report, last quarter coverage        ;
     *                                                         ;
     IF EN GE CORDATE AND ST LE  CORDATE AND ST GT REPDATE THEN
DO;
        CAS  = CORDATE - ST;
        END;
     *                                                         ;
     *  For single quarter report, calculate coverage          ;
     *                                                         ;
     IF ST LE REPDATE AND CORDATE LE EN THEN DO;
        CAS  = CORDATE-REPDATE;
        END;
  END;
     *                                                         ;
     *  Calculate total report coverage                        ;
     *                                                         ;
     CASTOT = SUM(OF CAS1-CAS19);
     *                                                         ;
     *  convert coverage into a percent of quarter             ;
     *  GENERATE NR DAY NOT ATTRIBUTAL TO SUPPLY               ;
     DO OVER CAS;
        IF CASTOT GE 0;
        SUPDAY = (SUPHR/24)*CAS/CASTOT;
        IF SUPDAY GE CAS THEN SUPDAY=CAS;
        FILLER= (CAS-SUPDAY);
        IF FILLER GE 0 THEN OTHDAY=FILLER; ELSE OTHDAY= 0;
        END;
     FILE DATAOUT;
        DO OVER CAS;
           IF CAS GT 0 THEN
              PUT @1  I    2.
                  @4  _UIC 3.
                  @8  REPDATE YYMMDD6.
                 @16  CORDATE YYMMDD6.
                 @24  SEVER   1.
                 @26  SUPDAY  6.1
                 @34  REPLEV  1.
                 @36  EIC     $4.
                 @41  CAS     2.
                 @46  OTHDAY  2.;
        END;
```

APPENDIX D

PROGRAMS FOR MERGING PERSONNEL AND CASREP DATA

The program below creates a summary output of the casrep data which includes the ship unit identification code, the quarter and the total equipment downtime in days, the time awaiting parts, and the time down not awaiting parts which is merged matching ship and quarter with the personnel data. The next portion of the program merges the personnel and casrep information matching the data by ship and quarter.

```
DATA ONE;
   INFILE CASREP;
          INPUT     @1 QTR  2.
                    @4  TUIC $CHAR3.
                    @8  REPDATE YYMMDD6.
                   @16  CORDATE YYMMDD6.
                   @24  SEVER   1.
                   @26  SUPDAY  6.1
                   @34  REPLEV  1.
                   @36  EIC     $4.
                   @41  CAS     2.
                   @46  OTHDAY  2.;
DATA TWO;
   SET ONE;
   IF TUIC=' 28' THEN TUIC='028';
   IF TUIC=' 32' THEN TUIC='032';
   IF TUIC=' 33' THEN TUIC='033';
   IF TUIC=' 34' THEN TUIC='034';
PROC SUMMARY DATA=TWO; CLASS TUIC QTR;
     VAR SUPDAY CAS OTHDAY;
     OUTPUT OUT=SUMREP.CASSUM
     SUM= DWNSUP DWNTOT DWNOTHER;
DATA FOUR;
     SET SUMREP.CASSUM;
     IF _TYPE_ NE 3 THEN DELETE;
DATA FIVE;
   LENGTH TUIC $ 3;
   SET PERSON.PERSUM;
   IF _TYPE_ NE 3 THEN DELETE;
   TUIC = SUBSTR(UIC,4,3);
PROC SORT DATA=FOUR; BY TUIC QTR;
PROC SORT DATA=FIVE; BY TUIC QTR;
DATA SIX;
    MERGE FOUR FIVE; BY TUIC QTR;
PROC SORT DATA=SIX OUT=CASNPERS.ALLEMERG; BY TUIC QTR;
PROC PRINT DATA=CASNPERS.ALLEMERG;
```

The output data set contained the following variables: TUIC--a ship identifier, QTR--the quarter number, DOWNSUP--the time awaiting parts, DOWNOTHER--the downtime not awaiting parts, DOWNTOT--the total CASREP downtime during the quarter, MNAFQT--the mean of the Enginemen onboard AFQT scores, MNPAYGRD--the mean of the rate of the Enginemen onboard, QTRSEXP--the sum of the total quarters served onboard the ship by the Enginemen onboard, NRACTEX--number of Air conditioning techs onboard in the quarter, NRAUXTEX--number of auxiliary technicians (NEC 4381/4382) onboard in the quarter, NRHSGRAD--the number of high school graduates onboard, WILQIND--a variable generated by summing the DMDC codes for the rate of the Engineman onboard (E-7 is equal to 7, E-1 to 1, etc.).

APPENDIX E

SAMPLE REGRESSION PROGRAM

```
DATA ONE;
   SET CASNPERS.FINALMR;
       IF  TYPE  =3;
       IF TUIC =  '106' OR TUIC =  '052' OR TUIC =  '054' OR
TUIC = '699'
       THEN DELETE;
   PROC REG  SIMPLE DATA=ONE;
        MODEL DWNTOT =WEITZ NRAUXTEX;
        MODEL DWNTOT= NRAUXTEX NRHSGRAD;
        MODEL DWNTOT= NRAUXTEX NRACTEX;
        MODEL DWNTOT= NRAUXTEX QTRSEXP;
        MODEL DWNTOT= NRAUXTEX NRNONNEC;
        MODEL DWNTOT= NRAUXTEX;
        MODEL DWNTOT=NRACTEX;
        MODEL DWNTOT=WEITZ;
        MODEL DWNTOT=NRNONNEC;
        MODEL DWNTOT=NRHSGRAD;
        MODEL DWNTOT=QTRSEXP; PROC MEANS DATA=ONE MAXDEC=2 N
MEAN STDERR MIN MAX SUM STD VAR;
   VAR DWNTOT  DWNSUP DWNOTHER MNAFQT MNCURAGE  MNHYEC MNTOB
MNYRADS
       NRACTEX NRAUXTEX  NRHSGRAD NRNONNEC  MNPAYGRD QTRSEXP
WILQIND;
   PROC CORR DATA=ONE OUTP=TWO;
    VAR  DWNTOT DWNSUP  DWNOTHER  NRAUXTEX NRACTEX  NRNONNEC
NRHSGRAD
        QTRSEXP  WEITZ; PROC PRINT DATA= TWO; /* //
```

APPENDIX F

DESCRIPTION OF PERMANENT DATA BASE

A data base was established on permanent mass sotrage and on magnetic tape at Naval Postgraduate School. The data is in two forms: 1) the raw data on enginemen and non-designated firemen on the ships covered in this thesis, and 2) a data base created using Statistical Analysis System (SAS) software in the analysis for this thesis containing: information on CASREPS of auxiliary equipments on FFG-7 class ships covered in this thesis as received from American Management Systems Incorporated, and the merged file of CASREP and Personnel information on the ships covered in this analysis. These data bases are described in detail below.

A. RAW DATA

The personnel data on Enginemen (EN) and non-designated firemen (FN) is a binary file which has a logical record length of 1954 card columns. Each record is an observation on one individual which gives personal information on that person over the nineteen quarters covered in the analysis (October 1979 through June 1984). Each record is a series of repeated information on each individual. If the individual was not on one of the ships in the study conducted here, the card columns for that quarter contain filler zeros. The blocks contain personnel information for the people on the ships as indicated below:

Card column	Quarter covered
55-154	OCT-DEC 1979
155-254	JAN-MAR 1980
255-354	APR-JUN 1980
355-454	JUL-SEP 1980
455-554	OCT-DEC 1980
555-654	JAN-MAR 1981
655-754	APR-JUN 1981
755-854	JUL-SEP 1981
855-954	OCT-DEC 1981
955-1054	JAN-MAR 1982
1055-1154	APR-JUN 1982
1155-1254	JUL-SEP 1982
1255-1354	OCT-DEC 1982
1355-1454	JAN-MAR 1983
1455-1554	APR-JUN 1983
1555-1654	JUL-SEP 1983
1655-1754	OCT-DEC 1983
1755-1854	JAN-MAR 1984
1855-1954	APR-JUN 1984

The information contained in each quarterly record is as follows:

Card column	Information Description
51	Unique Identification Number
52	Renorm Flag
53-54	Filler
55-58	Unique Identification Number
59-60	Total Active Federal Military Service
61-62	DOD Primary Occupation Group
63-64	DOD Duty Occupation Group
65	Highest Year of Education
66	AFQT Percentile
67	Paygrade

68	Home of Record (STATE)
69-71	Date of Birth
72	Service
73	Race
74	Source of Entry
75	Filler
76	Marital Status
77	Number of Dependents
78	File Date
79	Ethnic Group
80	Race Ethnic
81	Sex
82	Education/Mental Category
83-84	DOD Secondary Occupation Code
85	Mental Category
86	Age at Entry
87	Current Age
88-94	Primary MOS
95-97	Separation Program Designator
98	Interservice Separation
99-101	Date of Separation
102-104	Basic Active Service Date
105-106	Estimated Termination of Service
107-108	Date of Current Paygrade
109-110	Date of Lateral Enlistment
111	Component
112	Year of Active Duty Service
113	Time in Grade
114-118	Flight Pay Status
119-121	Pay Entry Base Date
122	Score Group
123-128	Unit Identification Code
129	Spanish Surname Indicator
130-131	Filler
132-138	Duty MOS
130-145	Program Element Code
146-149	ZIP code
150-153	Name (first 4 characters)
154	Gain/Loss code
155-254	Repeat of information on individual for next quarter as described in paragraph above. For example, the Total Active Federal Military Service for an individual in the quarter JAN-MAR80 would be in columns 159-160.

and similarly for intervening quarters.

1855-1954	Information on individual for last quarter of the study as indicated in paragraph above.

B. SAS Files

The SAS file containing CASREP information is stored on magnetic tape number 588 under the following name: WILLIS.SAS.CASREP. This file contains the following information:

Label Name	Definition
CORDATE	Casualty correction date YYMMDD
REPDATE	Casualty report date YYMMDD
SEVER	1=C-2, 2=C-3, 3=C-4
SUPHR	Downtime awaiting parts in Hours.
UIC	Ship Unit Identification Code
EIC	Equipment Identification Code
NOMEN	Abbreviated equipment name.

The SAS file is stored on magnetic tape number 588 and on mass storage 4C under the DATA SET NAME=MSS.F0597.WEITZMAN. The SAS data set name is FINALMR. The data set contains the following information:

Label Name	Definition
DWNTOT	Total Downtime in a quarter in days.
DWNOTHER	Downtime not awaiting parts in a quarter in days.
DWNSUP	Downtime awaiting parts in a quarter in days.
WEITZ	Each ship's quarterly average downtime in days.
QTRSEXP	The sum of the time onboard in quarters the enginemen on a ship have spent on that ship.
NRAUXTEX	The number of auxiliary technicians (NEC 4381 and 4382) on a ship in a quarter.
NRACTEX	The number of air conditioning technicians (NEC 4294) on a ship in a quarter.
NRNONNEC	The number of enginemen on a ship in a quarter without an NEC.
NRHSGRAD	The number of enginemen on a ship in a quarter who are high school graduates.

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